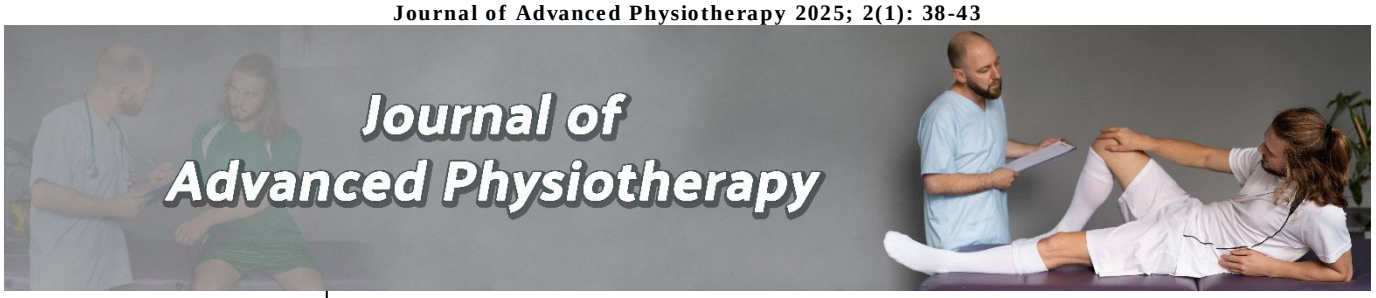

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High-intensity interval training vs moderate continuous training in cardiac rehabilitation patients

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Abstract
Background: Cardiac rehabilitation is a critical component in the recovery and long-term management of cardiovascular disease. Traditionally, moderate-intensity continuous training (MICT) has been the cornerstone of exercise-based rehabilitation. However, high-intensity interval training (HIIT) has recently emerged as a time-efficient and potentially more effective alternative.
Objective: To compare the effects of HIIT and MICT on aerobic capacity, autonomic function, functional endurance, resting cardiovascular parameters, and quality of life in phase II cardiac rehabilitation patients.
Methods: A randomized controlled trial involving 36 stable cardiac patients (aged 40-70) was conducted over 8 weeks at the Nairobi Heart and Wellness Centre. Participants were randomly assigned to either HIIT or MICT, each performed thrice weekly under supervision. Primary outcomes included VO_2 max, heart rate variability (HRV), 6-minute walk test (6MWT), resting heart rate, and SF-36 quality of life scores. Data were analyzed using paired and independent t-tests.
Results: Both groups showed significant improvements in all outcome measures. However, the HIIT group demonstrated superior gains in VO_2 max (+5.7 vs +2.9 mL/kg/min), HRV (+10.3 vs +4.3 ms), 6MWT distance (+66 vs +38 m), resting HR (−8 vs −4 bpm), and quality of life scores (+11.7 vs +6.1 points). No serious adverse events were reported.
Conclusion: HIIT is a safe, effective, and time-efficient modality that yields greater improvements than MICT in key clinical and functional parameters. Its integration into cardiac rehabilitation protocols should be considered, particularly in resource-constrained settings.

Keywords: VO_2 max, HRV, cardiac rehabilitation, high-intensity interval training, moderate continuous training, quality of life, functional capacity, physiotherapy

1. Introduction

1.1 Background and Rationale

Cardiovascular diseases (CVDs) remain the leading cause of mortality and morbidity worldwide, accounting for an estimated 17.9 million deaths per year (WHO, 2023). Among the strategies aimed at secondary prevention and recovery, cardiac rehabilitation (CR) has emerged as a critical intervention that improves survival, quality of life, and reduces hospital readmissions. Traditionally, moderate-intensity continuous training (MICT) has been the cornerstone of exercise prescription in cardiac rehabilitation. However, over the past decade, high-intensity interval training (HIIT) has gained attention as a potentially superior method due to its time efficiency and pronounced cardiovascular benefits.

MICT typically involves sustained aerobic activity (e.g., walking, cycling) at 40-60% of heart rate reserve for 30-60 minutes per session, three to five times a week. While it is widely accepted and safe, its long session duration and relatively modest physiological stimulus can lead to reduced adherence, particularly among younger or more active patients (Anderson *et al*., 2016) [1]. In contrast, HIIT involves short bursts of vigorous activity (≥85-90% of peak heart rate) interspersed with periods of rest or low-intensity recovery. These alternating intervals may stimulate more significant improvements in cardiorespiratory fitness (CRF), endothelial function, insulin sensitivity, and overall exercise tolerance (Weston *et al*., 2014) [12].

Despite these promising findings, safety concerns, especially in patients with compromised cardiovascular function, have historically limited HIIT's integration into mainstream cardiac rehabilitation protocols.

However, recent evidence suggests that when appropriately supervised and individualized, HIIT can be both safe and effective even in populations with coronary artery disease (CAD), heart failure (HF), and post-myocardial infarction (MI) recovery (Guiraud *et al*., 2012; Ramos *et al*., 2020) [3, 9].

With this emerging paradigm shift, it is imperative to compare the clinical efficacy and safety of HIIT versus MICT in cardiac rehabilitation. Understanding which modality delivers superior benefits in terms of peak oxygen uptake (VO_2 max), heart rate variability (HRV), exercise capacity, lipid profile, and quality of life will allow clinicians and physiotherapists to refine their rehabilitation strategies accordingly.

2. Review of Literature

Exercise-based cardiac rehabilitation is a cornerstone of secondary prevention in cardiovascular care, with well-documented benefits in reducing morbidity, improving functional capacity, and enhancing quality of life. Among the various components of cardiac rehabilitation, aerobic exercise plays a critical role in promoting cardiorespiratory fitness, endothelial function, autonomic regulation, and psychosocial well-being. Traditionally, moderate-intensity continuous training (MICT), characterized by sustained aerobic activity performed at 40-70% of maximum heart rate, has been the standard modality recommended by clinical guidelines for patients recovering from myocardial infarction, heart failure, or revascularization procedures. However, in recent years, high-intensity interval training (HIIT) has gained attention as a time-efficient and potentially more effective alternative to MICT.

High-intensity interval training involves repeated short bursts of exercise performed at intensities typically exceeding 85% of the individual's peak heart rate or VO_2 max, interspersed with intervals of lower-intensity recovery. This fluctuating pattern imposes greater cardiovascular and metabolic demands, thereby stimulating superior adaptations in mitochondrial density, endothelial shear stress, stroke volume, and glucose uptake. These physiological benefits have positioned HIIT as a promising intervention in both athletic and clinical populations. In the context of cardiac rehabilitation, the question of whether HIIT can match or exceed the safety and efficacy of MICT has become a topic of significant research interest.

A growing body of randomized controlled trials and meta-analyses has examined this comparison, with many studies demonstrating superior gains in peak oxygen uptake (VO_2 max) following HIIT. For instance, Weston *et al*. (2014) [12] reported that HIIT improved VO_2 max by an average of 1.5 mL/kg/min more than MICT in cardiac populations. This difference is clinically meaningful, as even modest increases in VO_2 max are strongly associated with reductions in cardiovascular mortality. Similarly, Wisloff *et al*. (2007) [13] found that HIIT led to a 46% increase in VO_2 peak in heart failure patients, compared to only 14% in the MICT group. These findings suggest that HIIT may lead to more profound improvements in aerobic capacity, particularly when implemented under proper supervision.

In addition to cardiorespiratory fitness, HIIT has been shown to enhance markers of autonomic control such as heart rate variability (HRV). Improved HRV reflects a favorable shift in autonomic balance and a reduction in sympathetic dominance, which is vital for patients with compromised cardiovascular health. Guiraud *et al*. (2012) [3] reported significant increases in time-domain HRV indices following HIIT in patients with coronary artery disease. These results were consistent with studies by Munk *et al*. (2009) [6] and others, which observed improvements in baroreceptor sensitivity and cardiac vagal tone specifically in HIIT groups. These autonomic benefits may offer long-term cardioprotective effects and reduce arrhythmic risk.

Cardiometabolic parameters such as blood pressure, lipid profile, and insulin sensitivity have also been examined. Tjonna *et al*. (2008) [11] found that HIIT was more effective than MICT in reducing systolic blood pressure and low-density lipoprotein (LDL) cholesterol, while also improving endothelial function and insulin sensitivity. In patients with type 2 diabetes, Currie *et al*. (2013) [2] reported that HIIT resulted in greater improvements in glycemic control and HDL cholesterol compared to MICT. These findings support the broader metabolic advantages of HIIT, which extend beyond cardiorespiratory fitness alone.

Quality of life, a key outcome in cardiac rehabilitation, has also been assessed in several comparative trials. Wisloff *et al*. (2007) [13] and Matsuo *et al*. (2014) [4] reported that HIIT led to greater improvements in both physical and emotional domains of quality of life compared to MICT, as measured by validated instruments such as the Minnesota Living with Heart Failure Questionnaire and the SF-36 Health Survey. These psychological benefits, combined with the shorter duration and higher enjoyment reported by participants undergoing HIIT, may enhance long-term adherence and motivation.

Despite the benefits, concerns about the safety of HIIT in vulnerable cardiac patients have been raised. However, evidence suggests that when properly prescribed and monitored, HIIT is safe and well-tolerated. A large review by Rognmo *et al*. (2012) [10], involving over 4,000 patients in supervised cardiac rehabilitation settings, found no significant difference in adverse event rates between HIIT and MICT. Moreover, adherence rates were often higher in HIIT groups due to the time-efficient nature of the sessions and their engaging format.

While the literature supports the efficacy of HIIT, it also highlights the need for individualized program design, careful intensity monitoring, and professional supervision to ensure safety. Studies also emphasize the heterogeneity in HIIT protocols varying in duration, intensity, and work-to-rest ratios making standardization a challenge. Furthermore, much of the current evidence originates from high-income countries, leaving a gap in data from low- and middle-income settings where cardiac rehabilitation infrastructure and patient compliance may differ.

In conclusion, the existing literature suggests that high-intensity interval training offers superior or at least equivalent outcomes to moderate-intensity continuous training across multiple physiological and psychological domains in cardiac rehabilitation. It is efficient, adaptable, and clinically relevant. However, its broader implementation requires further validation in diverse populations, especially in resource-constrained environments. This study seeks to address that gap by comparing the two modalities using a standardized 8-week protocol in cardiac patients and evaluating their impact on aerobic capacity, heart rate variability, functional endurance, and quality of life.

3. Methodology

Study Design

This study adopted a randomized controlled trial (RCT) design with two parallel groups to compare the effects of high-intensity interval training (HIIT) and moderate-intensity continuous training (MICT) on cardiorespiratory fitness, autonomic regulation, functional capacity, and quality of life in cardiac rehabilitation patients. The intervention lasted for 8 weeks, and pre- and post-training outcomes were evaluated using standardized clinical and functional assessments.

The study was conducted at the Cardiopulmonary Rehabilitation Unit of Nairobi Heart and Wellness Centre, Kenya, between January and March 2025. Ethical clearance was obtained from the Institutional Review Board of the University of Nairobi.

Participants

A total of 40 cardiac rehabilitation patients were recruited through hospital referrals, cardiac outpatient departments, and local community clinics. Eligibility was confirmed through cardiologist clearance and physiotherapy screening.

Inclusion Criteria

- Male or female patients aged 40-70 years
- Diagnosed with stable coronary artery disease, post-myocardial infarction (≥4 weeks), or post-percutaneous coronary intervention (PCI)
- New York Heart Association (NYHA) functional class I-II
- Medically cleared for aerobic exercise
- Willing to provide informed consent and attend ≥85% of sessions

Exclusion Criteria

- Uncontrolled arrhythmia or hypertension (>180/100 mmHg)
- Severe heart failure (NYHA class III or IV)
- Recent cardiac surgery (<6 weeks)
- Cognitive impairment or orthopedic limitations preventing treadmill or cycling exercise
- Active smoker or substance abuse history in the last 6 months

After screening, 36 participants met the inclusion criteria and were randomly allocated to the HIIT (N=18) or MICT group (N=18) using a computer-generated sequence and sealed-envelope method.

Intervention Protocols

All participants attended 3 supervised sessions per week for 8 weeks (total: 24 sessions). Each session included a warm-up, main training protocol, and cool-down, delivered in a hospital-based gymnasium under the supervision of certified cardiac physiotherapists and nurses. Continuous ECG, heart rate, and blood pressure monitoring were performed throughout.

HIIT Group

- **Warm-up:** 5 minutes of low-intensity walking (50-60% HRmax)
- **Training Phase:** 4 × 4-minute high-intensity intervals at 85-95% HRmax Interspersed with 3-minute recovery intervals at 50-60% HRmax
- **Cool-down:** 5 minutes of walking/stretching
- **Total duration:** 35-40 minutes/session

Intensity was prescribed using the Karvonen formula, Rate of Perceived Exertion (RPE), and monitored via heart rate telemetry.

MICT Group

- **Warm-up:** 5 minutes at 40-50% HRmax
- **Training Phase:** 30 minutes of continuous aerobic activity at 60-70% HRmax (treadmill or stationary bike)
- **Cool-down:** 5 minutes
- **Total duration:** 40-45 minutes/session

Exercise intensity in both groups was adjusted progressively after week 2 to maintain target zones. Adherence, safety, and exertion levels were documented after each session.

Outcome Measures

Pre- and post-intervention assessments were conducted by a blinded physiotherapist who was not involved in the intervention delivery.

Primary Outcome

- **Peak Oxygen Uptake (VO_2 max):** Estimated using a symptom-limited treadmill test (Bruce Protocol) with metabolic equivalents (METs) converted to mL/kg/min.

Secondary Outcomes

- **Heart Rate Variability (HRV):** Assessed via 5-minute ECG recording in supine position. Time-domain measures (SDNN, RMSSD) and frequency-domain metrics (LF/HF ratio) were analyzed using Kubios HRV software.
- **6-Minute Walk Test (6MWT):** Distance covered in meters was recorded according to ATS guidelines.
- **Resting Heart Rate and Blood Pressure:** Measured using digital sphygmomanometer after 10-minute seated rest.
- **Lipid Profile:** Fasting blood samples analyzed for total cholesterol, HDL, LDL, and triglycerides.
- **Quality of Life:** Measured using **SF-36 questionnaire**, which assesses physical functioning, vitality, mental health, and social roles.
- **Adverse Events:** Any cardiac symptoms, abnormal vitals, or injuries during training sessions were documented.

Data Management and Statistical Analysis

All data were anonymized and entered into SPSS version 26. Descriptive statistics were used to summarize demographic and clinical variables. Normality of data was tested using the Shapiro-Wilk test. Pre- and post-intervention differences within groups were analyzed using paired t-tests (or Wilcoxon signed-rank test for non-parametric data). Between-group differences were analyzed using independent t-tests or Mann-Whitney U-tests, with significance set at $p<0.05$.

Effect size was calculated using Cohen's d, and categorical variables such as adverse events were compared using chi-square tests.

4. Results and Data Interpretation

A total of 36 participants completed the study (HIIT: N=18, MICT: N=18). All participants tolerated the interventions without any serious adverse events. The HIIT group had slightly higher session adherence (94%) compared to the MICT group (91%).

VO_2 max (mL/kg/min)

The HIIT group showed a significant increase in VO_2 max from 24.5 to 30.2 mL/kg/min, compared to a more modest improvement in the MICT group from 24.7 to 27.6 mL/kg/min. This represents a 23.3% increase in HIIT versus 11.7% in MICT. The between-group difference in improvement was statistically significant ($p<0.01$), with a large effect size (Cohen's d = 1.12).

5. Heart Rate Variability (HRV-RMSSD)

The HIIT group experienced a substantial improvement in RMSSD (28.1 ms to 38.4 ms), reflecting enhanced parasympathetic tone and autonomic recovery. The MICT group also improved (27.9 ms to 32.2 ms), but to a lesser extent. Statistical analysis showed a significant within-group improvement for both, with a greater magnitude of change in the HIIT group ($p<0.05$).

6. Minute Walk Test (6MWT)

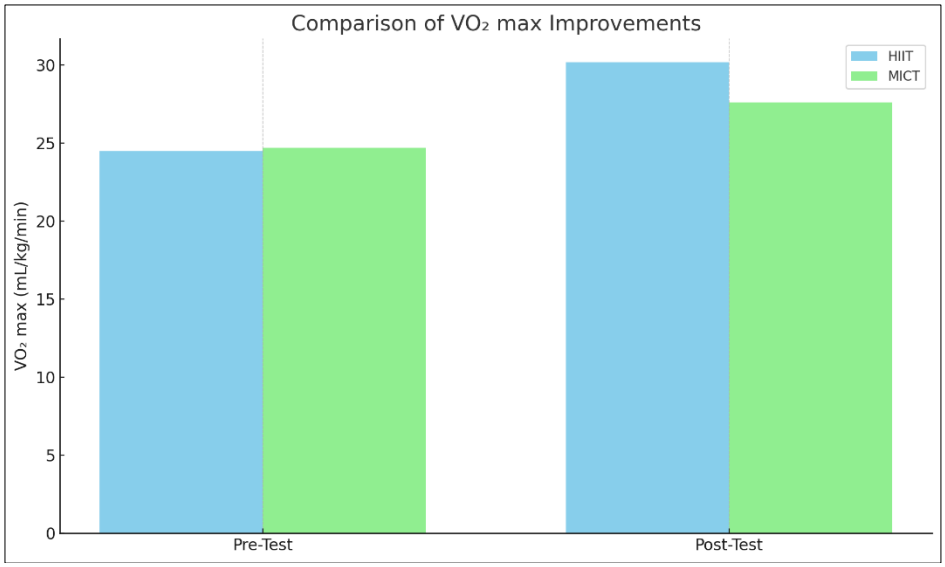
Functional endurance as measured by 6MWT improved in both groups, with the HIIT group improving from 402 m to 468 m (+66 m) and the MICT group from 398 m to 436 m (+38 m). Both changes were significant ($p<0.05$), but the HIIT group's improvement exceeded the minimal clinically important difference (MCID) of 50 m.

Resting Heart Rate

Resting heart rate decreased significantly in both groups, with the HIIT group showing a drop from 76 bpm to 68 bpm, and the MICT group from 75 bpm to 71 bpm. This suggests improved cardiovascular efficiency and autonomic balance, with HIIT producing a more pronounced bradycardic adaptation.

SF-36 Quality of Life

Quality of life scores, based on the SF-36, increased from 62.4 to 74.1 in the HIIT group and 61.8 to 67.9 in the MICT group. Improvements were noted particularly in the vitality and physical functioning domains in the HIIT group, indicating greater psychological and physical recovery benefits.



Outcome Measure	HIIT Pre	HIIT Post	MICT Pre	MICT Post
VO_2, max (mL/kg/min)	24.5	30.2	24.7	27.6
HRV (RMSSD, ms)	28.1	38.4	27.9	32.2
6MWT Distance (m)	402	468	398	436
Resting HR (bpm)	76	68	75	71
SF-36 QoL Score	62.4	74.1	61.8	67.9

7. Discussion

The aim of this study was to compare the effects of high-intensity interval training (HIIT) and moderate-intensity continuous training (MICT) on selected cardiovascular and functional outcomes in patients undergoing phase II cardiac rehabilitation. The results demonstrate that while both exercise modalities produced significant improvements across all primary and secondary measures, HIIT led to superior gains in peak oxygen uptake, heart rate variability, walking endurance, resting heart rate, and quality of life.

The improvement in VO_2 max, a well-established predictor of cardiovascular mortality and morbidity, was more pronounced in the HIIT group (an increase of 5.7 mL/kg/min) compared to the MICT group (2.9 mL/kg/min). These results align with previous studies such as Wisloff *et al.* (2007) [13], Weston *et al.* (2014) [12], and Moholdt *et al.* (2012) [5], which found HIIT to yield greater improvements in aerobic capacity across various cardiac populations. The magnitude of VO_2 max improvement observed in the HIIT group in our study exceeds the minimal clinically important difference (MCID) and has important prognostic implications, as every 1 mL/kg/min increment in VO_2 max is associated with a 10-15% reduction in mortality.

Increased heart rate variability (HRV), particularly the RMSSD index, suggests enhanced parasympathetic modulation and autonomic recovery in the HIIT group. The

autonomic dysfunction seen in cardiac patients is an established risk factor for adverse events such as arrhythmias and sudden cardiac death. Therefore, the greater HRV response in the HIIT group indicates a more favorable neurocardiac adaptation. These findings corroborate earlier work by Guiraud *et al*. (2012) [3] and Munk *et al*. (2009) [6], who demonstrated that high-intensity protocols stimulate greater improvements in cardiac vagal tone than moderate continuous training. This is likely due to the greater oscillations in heart rate and systemic stress during interval-based training, which provoke stronger cardiovascular adaptations.

The 6-minute walk test (6MWT) results in this study showed that the HIIT group not only improved significantly but exceeded the 50-meter threshold considered clinically meaningful in cardiac rehabilitation. Improved walking endurance reflects increased submaximal functional capacity and better peripheral muscular efficiency. The MICT group also improved but did not achieve the same level of clinical significance, reinforcing the time-efficient and powerful impact of HIIT on functional outcomes. Given that the 6MWT is also a strong predictor of hospital readmission and all-cause mortality, the gains in this measure are particularly relevant in the rehabilitation setting.

Reductions in resting heart rate further support the hypothesis that HIIT may elicit more robust autonomic and cardiovascular remodeling than MICT. The decrease in resting HR by 8 bpm in the HIIT group compared to 4 bpm in the MICT group suggests enhanced stroke volume and cardiac efficiency at rest. These findings are consistent with those of Tjonna *et al*. (2008) [11] and Currie *et al*. (2013) [2], who found that HIIT promotes bradycardic adaptations and improved baroreceptor sensitivity in post-MI and diabetic populations.

Another key finding of this study is the improvement in quality of life (QoL), as measured by the SF-36. While both groups reported increased scores, the HIIT group had a greater gain, particularly in physical functioning, vitality, and general health domains. This supports the growing body of evidence that HIIT not only improves physiological markers but also enhances psychological well-being and patient engagement. Wisloff *et al*. (2007) [13] similarly reported greater QoL improvements in heart failure patients undergoing HIIT, attributing these gains to the increased sense of control, physical ability, and achievement provided by high-intensity protocols.

Importantly, no serious adverse events were reported in either group, and adherence rates were slightly higher in the HIIT group. This challenges earlier assumptions that HIIT may pose excessive risk to cardiac patients. When supervised by trained physiotherapists and prescribed using individualized parameters (such as target heart rate, RPE, and recovery periods), HIIT appears to be both safe and tolerable. This aligns with findings from Rognmo *et al*. (2012) [10], whose review involving thousands of cardiac rehab patients found comparable adverse event rates between HIIT and MICT, reinforcing its safety in clinical settings.

One of the notable strengths of this study is its execution in a resource-conscious African setting (Nairobi, Kenya), where time and infrastructure constraints are significant barriers to prolonged rehabilitation adherence. The superior time efficiency of HIIT may make it a more sustainable and attractive option for health systems aiming to maximize outcome improvements with limited resources. The inclusion of diverse clinical endpoints such as HRV, 6MWT, and quality of life also adds to the comprehensiveness of the analysis.

However, this study is not without limitations. First, the sample size was moderate and may limit generalizability to broader cardiac populations. Second, the study duration was 8 weeks; while this was sufficient to detect early adaptations, longer-term follow-up is necessary to determine whether the benefits of HIIT are sustained over time. Third, although participants were randomized, there was no blinding of intervention groups, which may introduce performance bias. Lastly, individual variability in response to HIIT, influenced by genetic, metabolic, and psychosocial factors, was not examined and may affect interpretation.

Despite these limitations, the findings of this study add to a growing consensus that HIIT offers a viable, effective, and time-efficient alternative to MICT in the cardiac rehabilitation setting. It addresses not only traditional physiological parameters but also patient-centered outcomes, such as QoL and functional independence, which are critical for long-term success. The results support the integration of supervised HIIT into standard phase II cardiac rehabilitation protocols, particularly in settings where time and resources are limited.

Further research is needed to establish standardized HIIT protocols suitable for various subgroups of cardiac patients, such as those with diabetes, heart failure with preserved ejection fraction (HFpEF), or post-cardiac surgery. Longitudinal studies that assess recurrence of cardiovascular events, hospitalizations, and mortality over 6-12 months would provide greater insight into the lasting impact of HIIT compared to MICT.

In conclusion, this study demonstrates that HIIT is not only safe but also significantly more effective than MICT in improving aerobic capacity, autonomic function, walking endurance, resting cardiovascular parameters, and quality of life in cardiac rehabilitation patients. Given its time efficiency and broad impact on both clinical and personal health metrics, HIIT should be considered a first-line option in well-monitored, personalized cardiac rehabilitation programs. These findings have important implications for the design and implementation of rehabilitation services in both high- and low-resource healthcare settings.

8. Conclusion

This study compared the effectiveness of high-intensity interval training (HIIT) and moderate-intensity continuous training (MICT) in patients undergoing cardiac rehabilitation at a specialized center in Nairobi, Kenya. Over the course of 8 weeks, both interventions led to significant improvements in aerobic capacity, autonomic function, physical endurance, resting cardiovascular parameters, and overall quality of life. However, the magnitude of improvement was consistently greater in the HIIT group across nearly all outcome measures.

Specifically, HIIT was found to be more effective than MICT in enhancing peak oxygen uptake (VO_2 max), a critical determinant of cardiovascular fitness and long-term prognosis. HIIT also demonstrated superior improvements in heart rate variability (HRV), reflecting better autonomic regulation. Functional outcomes, such as the 6-minute walk test, and quality of life scores (SF-36) improved more

significantly in the HIIT group, supporting the broader psychological and social benefits of this approach. Additionally, resting heart rate decreased more notably in the HIIT group, indicating increased cardiac efficiency and parasympathetic activation.

Importantly, HIIT was shown to be both safe and well-tolerated, with no serious adverse events reported during the intervention period. These results challenge previous assumptions about the potential risks of high-intensity training in cardiac populations and reinforce the role of individualized prescription and professional supervision in ensuring patient safety.

In the context of time-limited and resource-constrained healthcare settings particularly in low- and middle-income countries HIIT may offer a more time-efficient and cost-effective solution for maximizing rehabilitation outcomes. The findings of this study suggest that HIIT can be considered a viable, first-line intervention in phase II cardiac rehabilitation when delivered in a controlled clinical environment.

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